Trends in penetration and ownership of household appliances

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Abstract

Since appliances consume a large fraction of the residential final energy consumption, analysing the impact and trends in penetration and ownership of appliances are targets of interest to researchers, companies and policy makers. However, there is a lack of published data based on the study of appliance penetration or ownership comparing different countries trends and assessing different appliances families. The data is usually found in percentages related to energy use or other factors, or in national directive documents written in local languages. The main aim of this paper is to analyse the trends in appliances penetration and/or ownership in the residential buildings sector providing access to the data of ten countries representing different world areas, and 20 appliances which fell into three distinct appliance categories (white goods, brown goods and small appliances), in a comparable framework. Penetration data is given for Australia, Austria, Denmark, France, Spain, UK, and USA; and ownership data for Australia, China, Hungary, Japan and USA.

Keywords: household appliances; penetration; ownership; trends

1. Introduction

In the next decades, the energy consumption of residential sector will rise due to the proliferation of equipment types used and their increased ownership and use. The 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) [1] stated that energy efficient appliances, lighting, information communication, and media technologies can reduce the substantial increase in electricity use expected. Global building energy use may

double to triple by 2050 due to several reasons, such as lack of access to adequate housing, lack of access to electricity, use of highly-polluting and unhealthy traditional solid fuels for household cooking and heating, migration of population to cities, decreasing household size, increasing levels of wealth and lifestyle changes, increasing types and number of appliances and equipment and their use [2].

In 2010 buildings accounted for 32 % of total global final energy consumption (24 % for residential and 8 % for commercial) [3]. Appliances represent 9 % of this energy consumption in residential buildings, which comprised 180 GWh in 2010 (Figure 1).

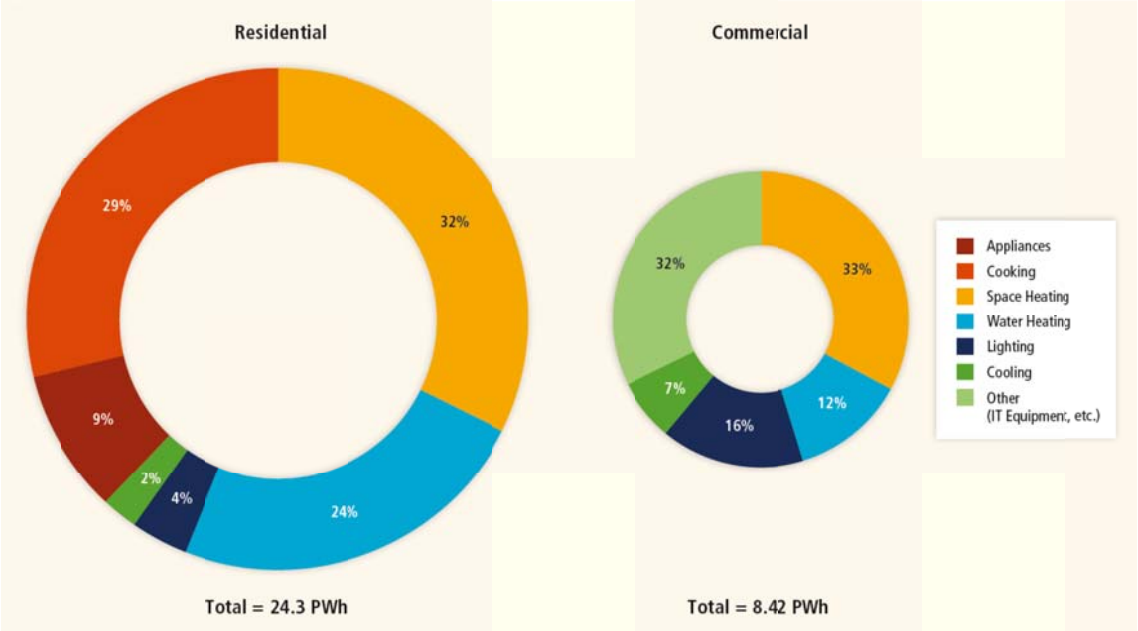


Figure 1. World building final energy consumption by end-use in 2010 [1][3] (IEA).

Understanding of how and why appliances have increased its penetration in residential buildings sector is substantially important to evaluate the changes in social customs, human habits and generational changes over time. This paper is focused to analyse the appliances penetration and ownership in residential sector for developed countries, part of the organisation for economic co-operation and development, in the period from 1970 to 2010. The structure of the paper is as follows; Section 2 reviews the previous literature and detailed objectives of the paper. Section 3 presents the methodology, sources acceded, countries and appliances included in the study. Results are presented and discussed in Section 4. Section 5 offers the main conclusions.

2. State of the art

The authors have assessed a brief state of the art basing the search for papers on ownership and penetration of household appliances all over the world. The 21 papers found in the literature review are shown in Table 1. The paper includes the main aim of the study, the periods of time included in the study, the country object of the study, the set of appliances, and the type of data studied; ownership or penetration. Distinguish between penetration and ownership is important to process the data collected correctly. Appliance penetration refers to the number of households using at least one of the given appliance, regardless of the number of items (penetration can be maximum 100 %), while appliance ownership refers to the total number of one specific appliance in the total of households (it is not always shown in percentage and not maximum is applied).

From the literature review the authors concluded that it is difficult to find data on appliance penetration or ownership for different countries and large amount of appliance from different categories. Furthermore, data found is usually related to studies that present values in percentages of the energy use or of other factors. In these studies, data normally shows ownership of appliances collected via questionnaire in a statistically representative sample in a given city or part of the country (like south-east). Such as in Lyons et al. [4], authors correlated domestic ownership of water-using appliances in the Republic of Ireland. No absolute ownership values are included in this study [4], but a regression analysis to examine the determinants of the water and sewage main connection status of Irish homes and to identify the characteristics of households that are associated with having larger or smaller numbers of appliances is done. Conversely, Leahy et al. [5] explored the factors affecting residential energy demand conditional on appliance ownership. Similarly, data from Mexico can be found in Rosas et al. [6] where authors studied the penetration of appliances in Mexican households according to income, giving ownership data, and studied its implications on commercial energy use and CO_2 emissions in 1996 and 2006. In Cyprus, some data can be found in Abeliotis et al. [7] who carried out a questionnaire to 186 inhabitants of the city of Limasol to identify the factors affecting consumers' preferences towards the ownership of household appliances. Brazil was used as case study in Pereira and Assis [8]. In such study [8], authors analysed the energy consumption of different building types grouped by residential sectors in different areas of the city. Won and Hong [9] studied the difference between home appliance ownership status and burden on electric rates according to different number of household members in Korea. A survey in Turkey by Sahin and Koksal [10] determined the importance of standby electricity consumption by domestic appliances. Nie and Kemp [11] studied the case of China and how energy use in residential buildings is affected by the number of appliances and their energy

efficiency, and its importance over other factors such as floor space, population and energy mix. The effects of the increase in usage of domestic computers in UK were evaluated by Terry and Palmer [12]. Finally, in USA Yang et al. [13] recognized on-line surveys as a cheap and efficient way to collect data on residential appliances. Other authors intended to relate moving home [14], social habits [15], demographic changes [16], and income structure [17] to the ownership of appliances in developed countries such as United Kingdom, United States, and Japan. Concluding that appliances ownership rates are strongly dependent to social and lifestyle changes. Interestingly, most of the papers found in the literature are trying to correlate the energy consumption and energy price changes to the ownership/penetration of appliances [17][24]. Goldschmidt [18] estimates the marginal annual energy (electricity and gas) consumption of domestic appliances and facilities in Western Australia, collecting the penetration from the Australian bureau of statistics (ABS). Herring [19] compared ownership and consumption of minor appliances in the UK to that in the US. Otherwise, Tippet et al. [23] and Rao and Ummel [24] related the appliances ownership to service life and affordability of appliances. Tippet et al. estimated the service life under one owner of selected major appliances (refrigerator, washing machine, clothes dryer, and dishwasher) according to selected characteristics of owner households in United States. Rao and Ummel examined the affordability and predict appliance penetration in developed and under developed countries. Moreover, only four papers comparing data from different countries were found; Herring [19], commented above, comparing UK and US ownership and appliances consumption, Meyers and Sathaye [20] studied changes in electricity use between 1970 and 1986 for 13 of the largest developing countries, Shipper et al. [22] examined the response of consumption to changes over time in developing countries part of the OECD, and Rao and Ummel [24] studied the appliance penetration comparing the affordability for developed and non-developed countries.

Overall, the main outcomes found in the literature review are listed below:

- United Kingdom and United States are the countries that have more studies on the penetration, ownership, and consumption of household appliances.
- There is a lack of studies assessing the penetration or ownership of household appliances in a large sample of countries and appliances categories.
- Most of the studies published are focused in the latest 90s and early 20s, evaluating the arrival of the technological era.
- The most studied appliances are: refrigerators, television, freezers, washing machine, clothes dryer, dishwasher, and microwave.
- The less studied appliances and not included in the studies are: lighting, air conditioner, small appliances such as hair dryer, shaver or fan, and new appliances such as tablet, smart phone, laptop, and music player.

- Most of the studies relate the appliances penetration to other parameters such as energy consumption, type of household, water usage, CO_2 emissions, moving home, etc.
- Most of the studies shows ownership and not penetration and interestingly do not distinguish between both data.

Table 1. State of the art of ownership and penetration papers.

Study	Country	Period of study	Appliances	Type of data	Ref
Correlate domestic ownership of water-using appliances	Ireland	2001-2002	Water-using appliances.	-	[4]
Examine the penetration of appliance according to income and CO2 emissions.	Mexico	1996-2006	Refrigerator, TV sets, washing machine, air conditioners, lighting, cooking and water heating.	Ownership data come from the national income–expenditure survey	[6]
Explore and report the attitudes of consumers on the ownership of household appliances.	Cyprus	2009-2010	Refrigerator, oven, washing machine, dishwasher, clothes dryer, Television, toaster, kitchen boiler, coffee maker and mixer/blender.	Ownership based on a survey.	[7]
Analyze the energy consumption for an building specific location	Brazil	1991-2000	Computer, television, radio, videocassette, video recorder, lighting, refrigerator, freezer, vacuum cleaner and microwave,	Ownership based on the socioeconomic data collected.	[8]
Evaluate the importance of electricity standby in household appliances.	Turkey	2012	Television, washing machine, dishwasher, clothes dryer, laptop, game console, DVD/VCD player, radio, microwave, oven, desktop, printer, clock, air conditioner, furnace, router, audio systems, phone, water cooler and satellite receiver.	Ownership based on surveys and data collected.	[10]
How energy use in residential buildings is affected by the number of appliances and their energy efficiency.	China	2002-2010	Television, washing machine, refrigerator, air conditioner and computer.	Ownership from China statistical yearbook (CSY) and authors calculations.	[11]
The effects of the increase in usage of domestic computers.	United Kingdom	1990-2012	Computer	Data from household electricity survey	[12]
Compare the results of Amazon Mechanical Turk online surveys with Residential Energy Consumption Survey (RECS) deployed by the US Energy Information Administration	United States	1978-2009	Televisions, freezers, refrigerators and ceiling fans	Ownership based on Amazon Mechanical Turk (AMT) surveys and Residential Energy Consumption Surveys (RECS) by US Energy Administration.	[13]
How appliance-using practices, and thereby appliance ownership levels, may change after moving home.	United Kingdom	2010-2011	Television, cooker, Washing machine, refrigerator, freezer, dishwasher, microwave oven, laptop/desktop/tablet and television.	Ownership extracted from DECC. (2013)	[14]
Examine electric appliance ownership status for different number of household members.	Korea	2013	Computer, audio, refrigerator, microwave oven, electric oven, electric rice cooker, electric iron, washing machine and electric cooker.	Ownership based on a questionnaire of 2250 around the nation.	[9]
Investigate the effects of appliance ownership and use of a broader range of appliances.	United Kingdom	2009-2010	Office equipment, laptop, telephony appliances, television, electric oven, electric hob, minor cooking appliances (microwave, toaster, etc.), refrigerator, freezer, dishwasher, washing machine and clothes dryer..	Ownership data based on a survey in Leicester (UK).	[15]
Estimate the marginal annual energy (electricity and gas) consumption of domestic appliances and facilities.	Western Australia	1990-1993	Air conditioning, room and water heating, refrigerator, microwave oven, electric and gas stove, washing machine, clothes dryer, dishwasher, wall and ceiling insulator.	Penetration rates extracted from the Australian bureau of statistics (ABS).	[18]
Compare ownership and consumption of minor appliances in the UK to that in the US	United Kingdom and United States	1981-1991	Iron, dishwasher, microwave, instant shower, vacuum cleaner, video recorders, electric blankets, radio/clocks, toaster, coffee maker and frypans.	Ownership extracted from Electricity Council and now the Electricity Association (UK) and data from US comes from papers published.	[19]

Describe changes in electricity use between 1970 and 1986 for 13 of the largest developing countries.	Bangkok, Taiwan, Singapore, Beijing, South Korea, Kuala Lumpur, Indonesia Urban, Philippines Urban	1970-1986	Refrigerator and air conditioners.	Ownership based on statistics published by energy statistics agencies, electric utilities, and other sources.	[20]
Estimate the variations in energy consumption per household and the aggregate annual consumption nationally.	United Kingdom	1994	Oven, microwave oven, refrigerator, freezer, television, video recorders, washing machine, dishwasher and tumble dryer.	Ownership based on a survey undertaken in the south-east of England.	[21]
Examine household energy use and appliance ownership.	Ireland	1990-2006	Refrigerator, freezer, vacuum cleaner, microwave, tumble dryer, dishwasher and home computer.	Ownership extracted from Central Statistics Office (CSO).	[5]
Examine how income structure and wealth determine the number of appliances in a household.	Japan	1967- 2015	Television, dishwasher, PC, air conditioner. Cellular phone, warm water bidet.	Ownership extracted from the Japanese National Survey of Family Income and Expenditure.	[17]
Determine the relationships of demographic variables, ownership of 11 appliances, and time spent in four categories of household tasks.	United States	1981	Vacuum cleaner, washing machine, clothes dryer, refrigerator, dishwasher, food waste disposer, auto cleaning oven, microwave oven, trash compactor.	Ownership extracted from a study of time use (NE-113) among two parent/two-child families.	[16]
Examine the response of consumption to changes over time in energy prices, household income, appliance saturations, dwelling type and size, building practices and energy policies.	OECD countries: Canada, Denmark, France, Germany, Great Britain, Italy, Japan, Netherlands, Norway, Sweden, United States.	1983	Refrigerator, freezer, washing machine, clothes dryer, dishwasher and oven.	Penetration	[22]
Estimate the service life under one owner of selected major appliances according to selected characteristics of owner households.	United States	1971-1972	Refrigerator, washing machine, clothes dryer and dishwasher.	Ownership extracted from survey data.	[23]
Examine the affordability and predict appliance penetration in developed and under developed countries.	Brazil, India, South Africa, United States, United kingdom, Germany, France, Japan, Albania, Armenia, China.2009-2012	2009-2012	Television, mobile phone, refrigerator and washing machine.	Penetration extracted from the dataset of each country (surveys institutions).	[24]

This paper is intended to complement the data presented in the literature review and to provide more information that might be helpful to politicians and researchers on the topic. The aim of this paper is to report and show the trends in appliance penetration and/or ownership in residential buildings for different countries of the world, representing different world regions. More specifically, the objectives are:

1. To search in data bases sort by country, appliances type, and year. Evaluating the feasibility of the search and how easy is to collect data and analysing it.
2. To maximize the data collected and the number of appliances under study. Trying to cover a large set of appliance and sample of countries.
3. To classify the data collected for each country following the appliances type classification (see Section 2.3) and ownership/penetration data.
4. To analyse the data collected from 1970 to 2010 by means of graphing the data collected in three different graphs for the three appliances categories.
5. To provide new data in the topic and show trends useful for other researchers to use in their studies.
6. To compare and examine the appliances ownership or/and penetration to residential energy consumption per capita, electricity consumption per capita and GDP per capita.

3. Methodology

In this section the methodology followed, sources accessed, countries, and appliances included in the study are presented.

3.1. Appliances classification

In the present paper appliances are split into three groups. The first one, white and goods, includes the appliances intended to cover basic needs such as washing machines, refrigerators or freezers, cloth dryers, dishwashers, etc. Brown good, which is the second group, includes the appliances aimed to fulfil secondary society needs from a technologic point of view; such appliances are normally used for leisure. A sample of appliances within this group are TVs, computers, DVDs, cameras, videogames, etc. Also, new appliances as tablets, smartphones, music players, GPS, etc. are included in this group. Such new appeared appliances are increasing considerably their impact because they respond to the new nexus between society networks and social media. The last group includes small appliances commonly used in households for housework and personal cleanliness. Irons, coffee makers, microwaves, mixers, hair dryers, fans, etc. are common examples of small appliances. Table 2 classifies appliances included in this study in each category described above.

Table 2. Appliances classification included in this study by category

White goods	Refrigerator	Oven
	Freezer	Air conditioner
	Washing machine	Gas cooker
	Clothes dryer	Electric cooker
	Dishwasher	Fridge-freezer
Brown goods	Television	Video camera
	Video recorder	Tablet
	Personal computer	Games machine
	Laptop	PC printer
	Mobile phone/ smart phone	Radio
	DVD player	Landline phone
	Desktop PCs	MP3/MP4
Small appliances	Microwave	Ceiling fan
	Toaster	Portable fan
	Coffee maker	Vacuum cleaner
	Electric fan	Stove

3.2. Countries considered

The countries considered in this case of study are part of the OECD, the countries and the reasons to add them in the set of countries are specified in this section.

1. Spain, France, Austria, Denmark, UK, and Hungary were considered to represent South, North, and East Europe areas, respectively. To compare the different climate zones in Europe as well as strong economies to countries in current economic growth. All the countries listed above except Hungary, which present ownership data, present penetration data (See Tables 3, 4 and 5).
2. USA was included in this study due to its worldwide importance and its high residential buildings consumption, partially due to appliance ownership, and comparable to that from the whole Europe. For USA, ownership and penetration was retrieved (See Tables 3, 4 and 5).

3. Interestingly, the cases of study registered in Asiatic countries are more difficult to compare due to their strong diversity and because the data is segmented and difficult to access. However, Japan and China were selected to represent the emerging economies in Asia Japan is a remarkable case within the first line of technology deployment since decades while China is an emergent country where the appliance ownership has increased considerably during the last decades. Ownership data is presented for Japan and China as shown in Tables 3, 4 and 5..
4. Australia is a peculiar case because of its remarkable singularities such as low population density within a huge country and because it is part of the OCDE although it is located in a very different climate zone compared to the rest of the OCDE countries. For Australia, penetration and ownership data is assessed (see Tables 3, 4 and 5). .

3.3. Data collection

In the present section, the data sources of the different countries considered are listed. Most of the data gathered was found in the statistical institutions of their respective countries either in the website or in the yearbooks published by the national institution. In some cases such as Hungary, Japan and China the data was difficult to access or only found in national libraries. The sources consulted as well as the data format and collection is detailed as follows:

- **Hungary:** the data was consulted in the *Statistical Yearbook of Hungary* [25][28] paper version available in the National Széchényi Library and compiled in excel files.
- **Spain:** the data was easily accessible in excel format in the website of the *Instituto Nacional de Estadística* [29]. The data distinguishes between the size of the dwelling and the location (big or small cities).
- **France:** the data was easily accessible in excel format in the website of the *Institute National de la Statistique et des Études Économiques* [30]. The data found was divided in between the family type (single parent, only-child, two-child, etc)
- **Austria:** the data was accessible in excel format in the website of the *Statistik Austria* [31]. The data was complemented with the reported values of household appliances penetration by Hass et al. [32]. The ownership data extracted from the statistics website was given per private household number not differentiating in between type of dwelling, income or type of family.
- **Denmark:** the data was easily accessible in excel format in the website of the Statistics Denmark [33]. The ownership data extracted from the statistics website was given per private household number not differentiating in between type of dwelling, income or type of family.
- **United Kingdom:** Department of Energy & Climate Change [34].

- **United States:** the data was easily accessible in excel format in the website of the U.S. Energy Information Administration (EIA) [35]. USA is the country that contains more data available in its Energy Administration website as well as more detailed data distinguishing between ownership and penetration, type of household, people leaving in the house, income, etc.
- **Japan:** The Institute of Energy Economics [36].
- **China:** Chinese Statistical yearbook [37][44].
- **Australia:** The data was collected from the Australian social trends yearly published by Australian Bureau of Statistics [45] and People´s views and practices published yearly by Department of Industry and Science [46] and Australian Bureau of Statistics. The ownership data extracted from the statistics website was not differentiating in between type of dwelling, income or type of family.

Since the data collected was distributed along the difference statistical websites and yearbooks, the years under study and the appliances considered are different for each country. For comparison purposes, the authors intended to unify the data comparing the same appliances and similar periods of time. To clarify the data collection methodology the periods of data that were found for each country and appliance are listed in Table 3 to Table 5. The white goods are listed in Table 3, while brown goods and small appliances are reported in Table 4 and Table 5, respectively. The white appliances are available for longer periods of times and the most common appliances are, as it was found in the literature review: freezer, refrigerator, washing machine, dishwasher, and clothes dryer. Regarding brown goods, television and personal computer are the most reported appliances from the early 70s (television) and 90s (personal computer) to 2010. However, small appliances are the less studied, as it was also concluded in the state of the arte undertaken, microwave is the one reported the most. Overall, China, Hungary and Japan are the countries presenting less data available while United States and Australia are the countries showing more data in appliances penetration and ownership.

Table 3. Periods of available data for white goods

Country	Type of data	Refrigerator	Freezer	Oven	Dishwasher	Washing machine	Clothes dryer	Air conditioner	Fridge + freezer	Gas /electric cooker
Austria	Penetration	1975-2010	1975-2010	---	1975-2010	1980-2010	1980-2010	---	---	1975-2010
Denmark		1990-2010	1990-2010	---	1990-2010	1990-2010	1990-2010	---	1990-2010	---
France		1997-2009	1997-2009	---	1997-2009	1997-2009	---	---	---	---
Spain		2000-2012	---	---	2000-2012	2000-2012	1975-2012	---	---	---
UK		---	---	---	1975-2000	1975-2000	---	---	---	---
USA	Penetration & Ownership	1993-2010	1993-2010	1993-2010	1993-2010	1993-2010	1993-2010	1993-2010	---	---
Australia		1995-2005	1995-2005	---	1995-2005	1995-2000	1995-2005	1995-2005	---	
China	Ownership	1980-2005	---	---	---	1980-2005	---	---	---	---
Hungary		1970-2012	---	---	---	1970-2012	---	---	---	---
Japan		1970-2003	---	---	---	---	---	---	---	---

Table 4. Periods of available data for brown goods.

Country	Type of data	Television	Personal computer	Video recorder	Laptop	PC Printer	Desktops PC's	Mobile phone	DVD player	Tablet PC minicomputer	Games machine	Smart phone	Video camera	Radio	Fixed line telephone	MP3-MP4
Austria	Penetration	1975-2010	1990-2010	1980-2010	---	---	---	1993-2010	---	---	---	---	1990-2010	---	1975-2010	---
Denmark		1990-1995	1990-2010	1995-2010	2010	---	---	1995-2010	1995-2010	2010	---	2010	---	---	---	2010
France		1997-2009	2004-2009	---	---	---	---	2004-2009	1997-2009	---	---	---	---	---	---	2004-2009
Spain		2002-2012	2002-2012	2003-2012	2002-2012	---	---	2002-2012	2002-2012	---	---	---	---	2002-2012	2002-2010	2002-2012
UK		1970-2000	1985-2000	---	---	---	---	---	---	---	---	---	---	---	---	---
USA	Penetration & ownership	1993-2010	1997-2010	1997-1995	2001-2010	2001-2010	2001-2010	2001-2010	1997-2010	---	---	---	---	---	---	---
Australia		1999-2005	1999-2005	19990-2005	---	---	---	1995-2005	2005	---	2005	---	---	---	---	---
China	Ownership	1980-2010	2000-2010	---	---	---	---	---	---	---	---	---	---	---	---	---
Hungary		1970-2012	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Japan		1970-2012	1985-2012	---	---	---	---	---	---	---	---	---	---	---	---	---

Table 5. Period of available data for small appliances

Country	Type of data	Microwave oven	Toaster	Electric coffee maker	Electric fan	Portable fan	Ceiling fan	Vacuum cleaner	Stove
Austria	Penetration	---	---	---	---	---	---	---	---
Denmark		1990-2010	---	---	---	---	---	---	---
France		1997-2009	---	---	---	---	---	---	---
Spain		---	---	---	---	---	---	---	---
UK		1994-1999	---	---	---	---	---	---	---
USA	Penetration & ownership	19932010	1993-2010	1993-2010	---	---	1993-2010	---	---
Australia		1999-2005	---	---	---	1999-2005	1999-2005	1999-2005	1995-2005
China	Ownership	---	---	---	190-2004	---	---	---	---
Hungary		---	---	---		---	---	1970-2004	---
Japan		---	---	---	---	---	---	---	---

4. Results

In this section, the data is graphed differentiating in between white goods, brown goods and small appliances. The data collected is divided into penetration data and ownership data following Table 3, Table 4 and Table 5. Also, a supportive graphic material has been added comparing the average device ownership increment for white goods, brown goods and small appliances in front of the residential energy consumption per capita, the electricity consumption per capita and GDP per capita.

4.1. Penetration data

4.1.1. Austria

The penetration of brown goods increased dramatically in Austria (see Figure 2); television dramatically raised from 11% in 1974 to saturation (100%) in 1998, while mobile phones achieved this growth in only 16 years (from 1993 to 2010). Video recorders and personal computer growth follow a similar trend, however, only up to around 76% penetration. Only video cameras showed a less pronounced slope at increase, growing proportionally from 1990 to 2010. Regarding white goods, all Austrian households already had a refrigerator in 1989 (100% saturation); otherwise, saturation was reached for washing machines in 2000 and for electric cookers in 2010 (Figure 2). Freezers penetration was constantly growing from 1980 to 2000 and steeper for dishwashers (those reached 73.7% ownership in 2010). Clothes dryers did not start growing until 1993, reaching a 34% in 2010. Interesting is the case of gas cookers; 31% households in Austria had a gas cooker in 1974 but 20% in 1993, then, this percentage has been decreasing steadily until 2010 when it reached 11%. On the other hand, electric cookers followed the opposite trend; 55% households in Austria had an electric cooker in 1974; this percentage increased during 1974-2010 reaching 90% of electric cooker ownership per household. Therefore, gas cooker was gradually substituted by electric cooker in the period of 1990-2010.

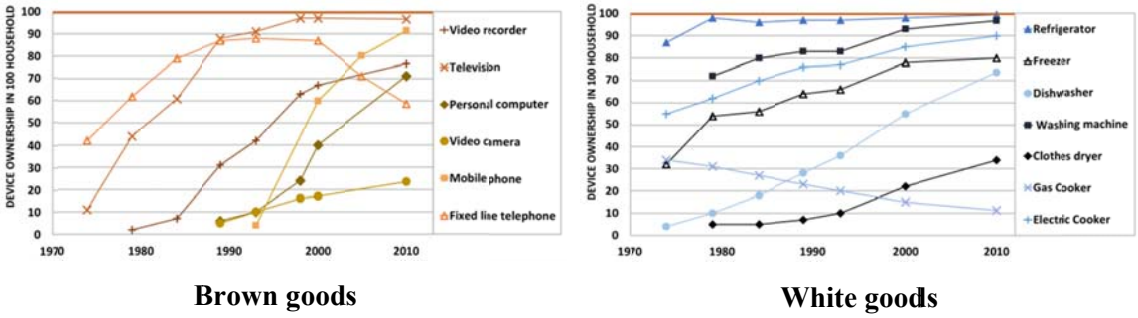


Figure 2. Penetration of domestic electrical appliances in Austria 1974-2010

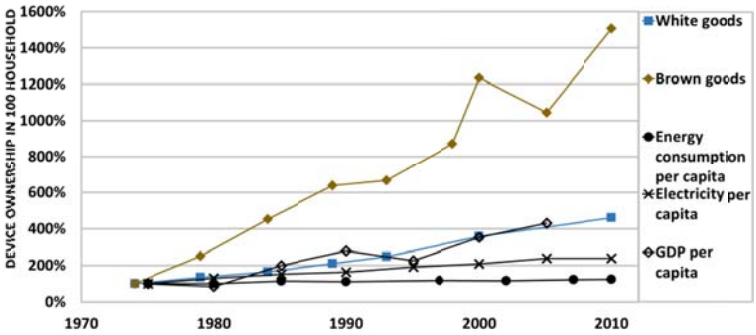


Figure 3. Trends in domestic electrical appliance penetration vs. residential energy consumption per capita, electricity consumption per capita and GDP per capita in Austria 1974-2010

Figure **3** The growth in appliance penetration in Austria followed a higher rate than the residential energy and electricity consumption per capita, but at the same rate as GDP per capita as it is shown in Figure 4. These trends can partially be explained by the decrease in energy consumption by appliance, as shown in Figure 4 for freezers, refrigerators and dishwashers. Figure 4 also shows that the total electricity consumption by appliance type did not decrease as the unit one, due to the growth in appliance ownership.

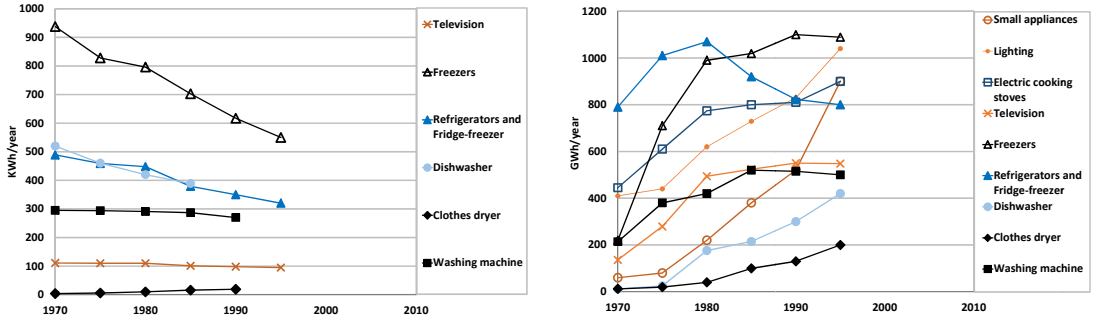


Figure 4. Development of unit electricity consumption (UEC) of different appliances (left) and total electricity consumption by appliance type (right) in Austria

4.1.2. Denmark

Denmark showed a steep growth in brown goods in the 90s (Figure 5); televisions and computers started their deployment in 1990, mobile phones, video cameras and DVD players in 1995, smart phones and tablet PC minicomputers in 2010. Within brown goods, only video cameras have a slope that seems to show that saturation will not be reached. It can be seen how video cameras has been gradually replaced by mobile phones and video recorders by DVD players especially in the beginning of the turn of the millennium. Small appliance ownership, represented just by microwave ovens, grew from 17% in 1990 to 76% in 2010.

White goods data from Denmark are presented for refrigerators (from 32% in 1990 to 97% in 2010), freezers (from 29% in 1990 to 89% in 2010), fridge-freezers (from 17% in 1990 to 72% in 2010), washing machines (from 70% in 1990 to 82% in 2010), clothes dryers (from 24% in 1990 to 54% in 2010), and dishwashers (from 29% in 1990 to 69% in 2010). Differently from the previous case, the stagnation is not reached for any of the white goods, not even for refrigerators. If the increment keeps constant, the refrigerator stagnation will be reached in the next decades.

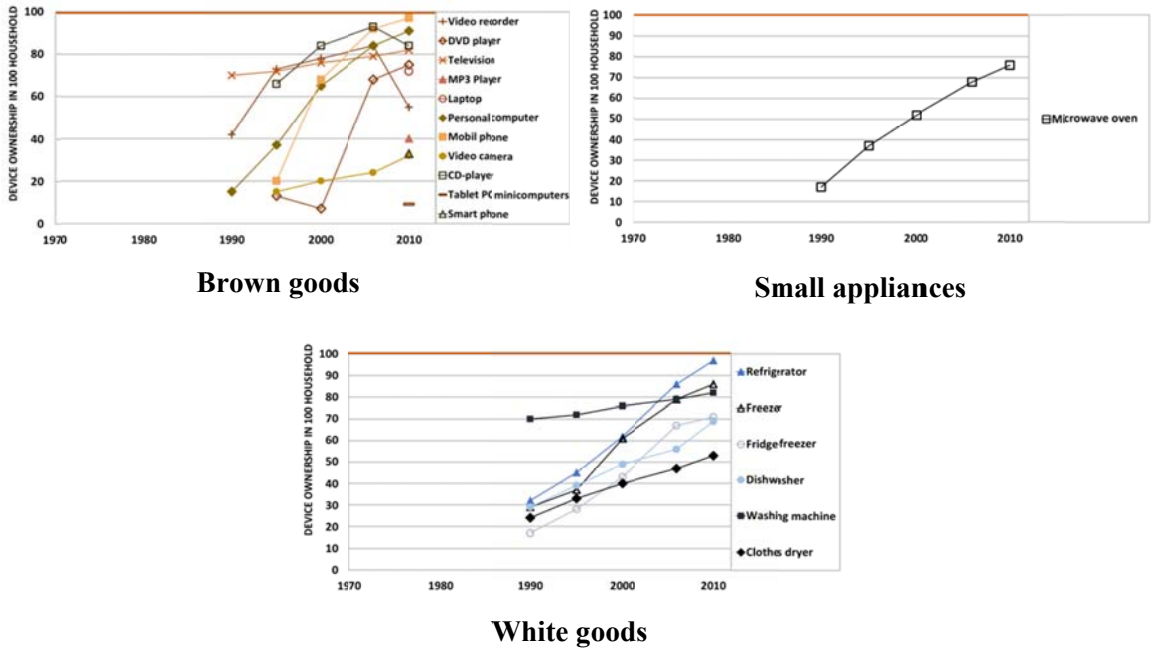


Figure 5. Penetration of domestic electrical appliances in Denmark 1990-2010

Following a trend representative from developed countries,, domestic electrical appliance penetration in Denmark grew at a high rate, however, residential energy and electricity

consumption per capita has not followed the dramatic increase in their penetration between 1990 to 2010 (Figure 6), and contrary to Austria, not even GDP per capita.

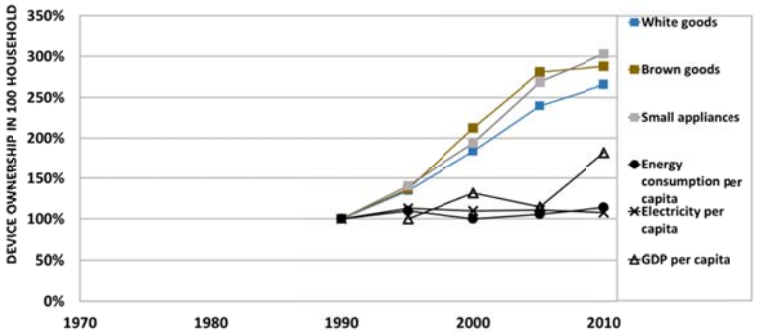


Figure 6. Trends in domestic electrical appliance penetration vs. residential energy consumption per capita, electricity consumption per capita and GDP per capita in Denmark 1970-2010

4.1.3. France

Most of the available data presented in this paper for France (Figure 7)revealed that saturation will be shortly reached to fulfil penetration during the period 1997-2009 (televisions, microwave ovens, and refrigerators) or stagnation at a value near saturation (landline phones, washing machines, and freezers). On the other hand, other appliances still show a steep increase rate such as mobile phones, personal computers, and dishwashers. From 1997 to 2009 the trends in domestic electrical appliance penetration were similar to the residential energy, electricity consumption and GDP per capita increase except for small appliance penetration, which increased at a much higher rate (Figure 8).

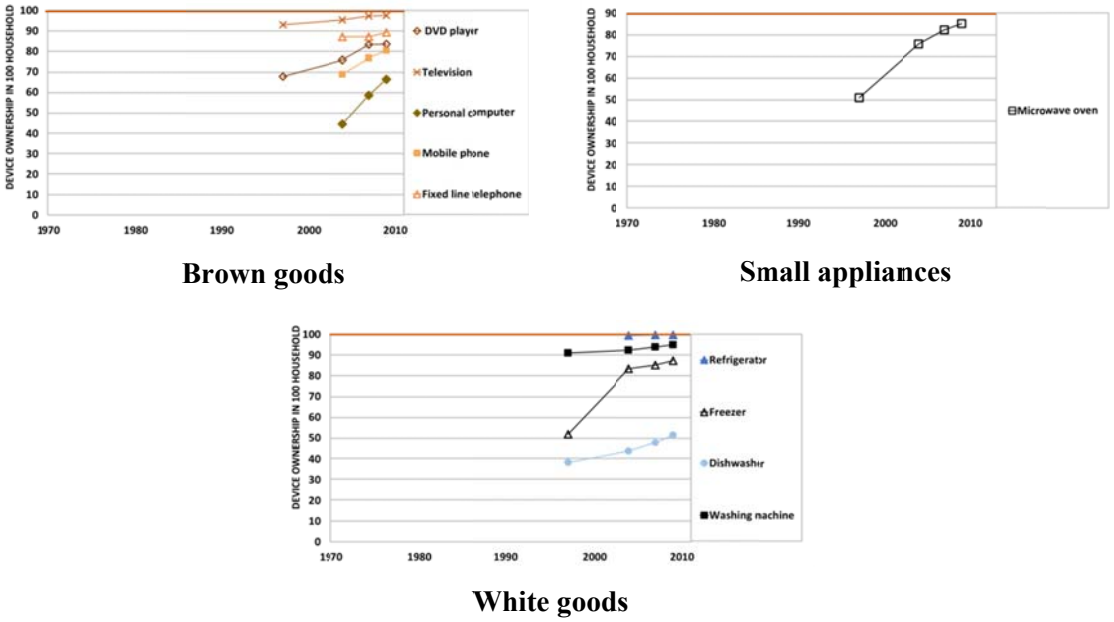


Figure 7. Penetration of domestic electrical appliances in France 1997-2009

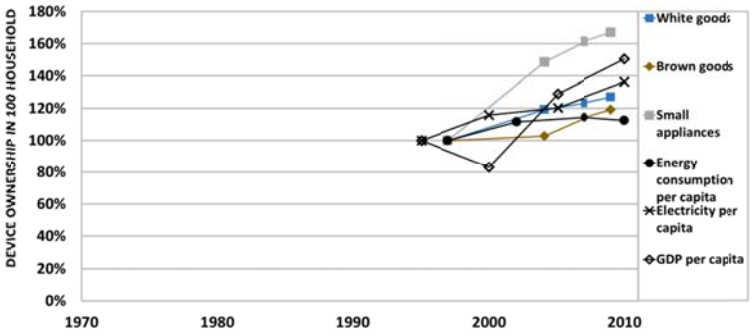


Figure 8. Trends in domestic electrical appliance penetration vs. residential energy consumption per capita, electricity consumption per capita and GDP per capita in France 1991-2010

4.1.4. Spain

Data on penetration of brown and white goods in Spain show no big growth since 2000 (Figure 9) except for laptops (increase from 9.5% in 2000 to 53% in 2012), DVD players (from 43% in 2000 to 73% in 2012), and dishwashers (from 41% in 2000 to 61% in 2012). Contrary and also predictable, video recorders penetration decreased from 75% in 2000 to 42% in 2012. As for Denmark, the video recorder was clearly replaced by DVD player from 2005 when the DVD ownership rates started to decrease. Maybe due to the appearance of blue ray or of online interfaces to watch movies and TV series. While the radio ownership decreased from 90% to 79 % in 2005-2010, some new music player appliances such as MP3 or MP4 started their deployment in 2009. In 2012, 46% households in Spain have an MP3 or MP4. Furthermore, the

fix telephone started to decrease at the same time mobile phone appeared to be common at Spanish households in 2000 (80%).

In comparison to Denmark or Austria, colder countries than Spain, the ownership of clothes dryer is really low. Just 5% of the household had a clothes dryer in 2005, this percentage grew up to 10% in 2010. Therefore, the tendency in Spain is to gradually increase the presence of clothes dryers at home. In Spain, the increase in white appliance penetration had a very similar trend to energy consumption per capita between 2000 and 2012, and brown goods to the trend of electricity consumption per capita. However, GDP per capita grew at higher trend (Figure 10). Therefore, even the population has higher purchasing capacity this fact is not directly linked to the appliances ownership and energy consumption.

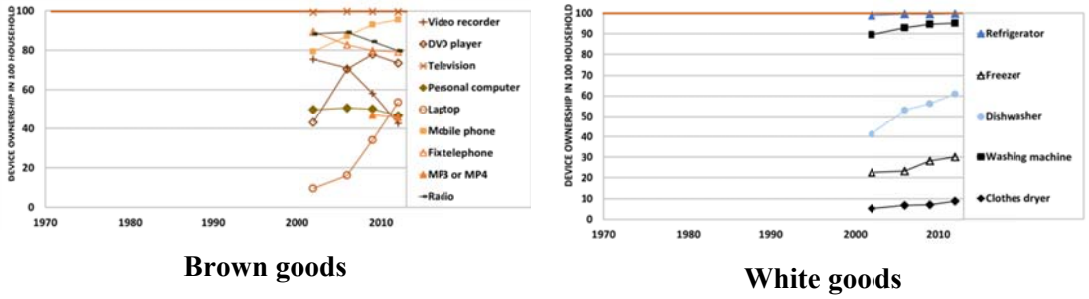


Figure 9. Penetration of domestic electrical appliances in Spain 2002-2012

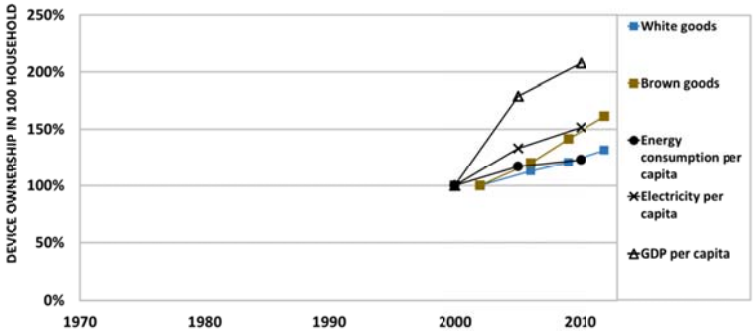


Figure 10. Trends in domestic electrical appliance penetration vs. residential energy consumption per capita, electricity consumption per capita and GDP per capita in Spain 2002-2012

4.1.5. UK

White goods penetration such as dishwashers and washing machines in UK did grow from 72% in 1975 to 93% in 2000 (Figure 11). Each UK household already had a television in 1975. Computers could only be found in 10% UK households in 1985 and in 40% households in 2000. Similarly, microwave oven penetration was 67% in 1994 and 80% in 2000. Trends in UK appliance penetration which data is available are similar to those of energy and electricity

consumption per capita (Figure 12), while GDP per capita growing is considerably higher, similarly to the case of Spain.

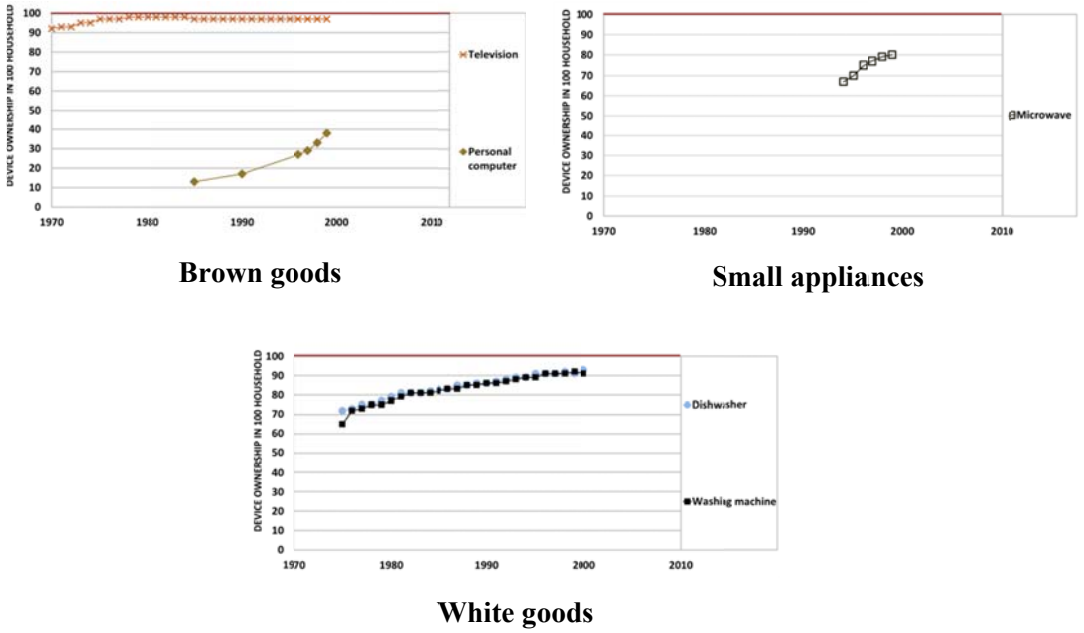


Figure 11. Penetration of domestic electrical appliances in United Kingdom 1970-2000

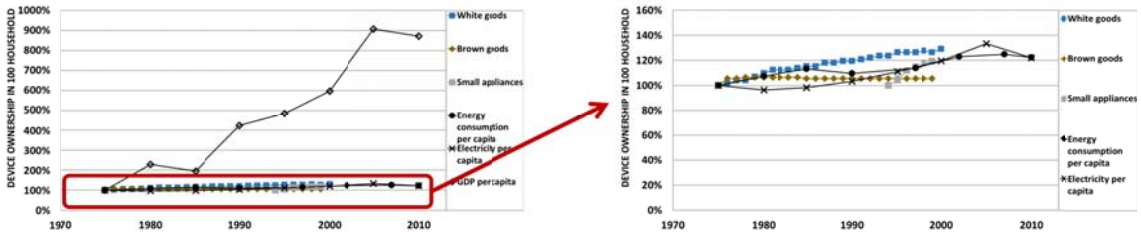


Figure 12. Trends in domestic electrical appliances vs. residential energy consumption per capita, electricity consumption per capita and GDP per capita in United Kingdom 1970-2010. Note: Year 1975 is reference year (100%)

4.2. Penetration and ownership data

4.2.1. Australia

Data on appliance penetration for Australia is presented since 1994 to 2005 in Figure 13. Brown goods considered are games machines, video recorders, DVD players, personal computers and televisions. Television penetration was around 99% in 1999, DVD players was around 72% in 2005, video recorders varied between 84% and 89% showing a decrease trend after 2002, game machines were in the 30.8% households in 2005, and personal computer showed a very steep growth from 2000 (around 45%) to 2005 (68%). Most of the small appliances in Australia

stagnated in 2000 at different penetration values: average of 44% for ceiling fans, 80% for stoves and 97% for vacuum cleaners. Considered white goods are refrigerators, freezers, dishwashers, washing machines, clothes dryers, and air conditioners. 99.9% households already had a refrigerator in 1995 while freezers penetration is decreasing from 45% to 37%. Washing machines penetration shows stagnation around 95%, while clothes dryers around 55% since 1995. Dishwashers penetration is growing from 25% to 41% in the period considered (1970-2010), and air conditioners from 32% to 60%.

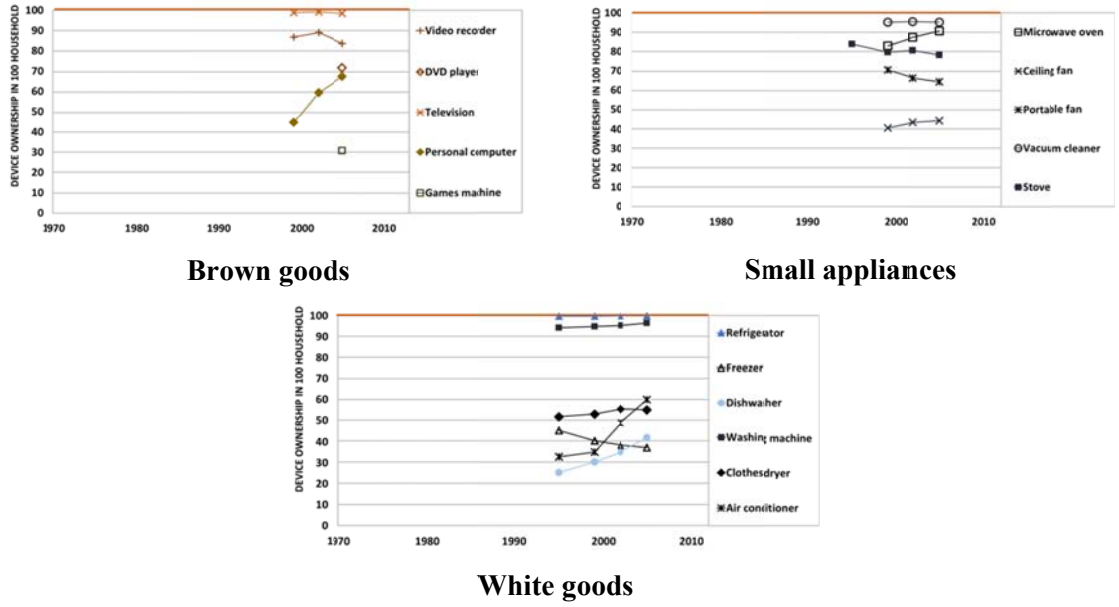
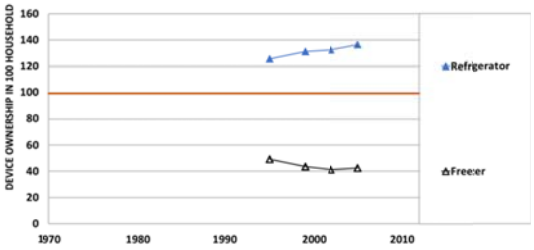


Figure 13. Penetration of domestic electrical appliances in Australia 1995-2005

Data for appliance ownership in Australia is only available for white goods; refrigerators and freezers. Freezers ownership between 1995 and 2005 (Figure 14) is very similar to the data on penetration (Figure 13). For refrigerators, differences between penetration (99.9% in Figure 13) and ownership (125% to 136% in Figure 14) can be clearly seen. Figure 15 shows that the growth in white and brown goods ownership in Australia had similar trends to energy and electricity consumption per capita while GDP per capita grew substantially more.



White goods

Figure 14. Ownership of domestic electrical appliances in Australia 1995-2005

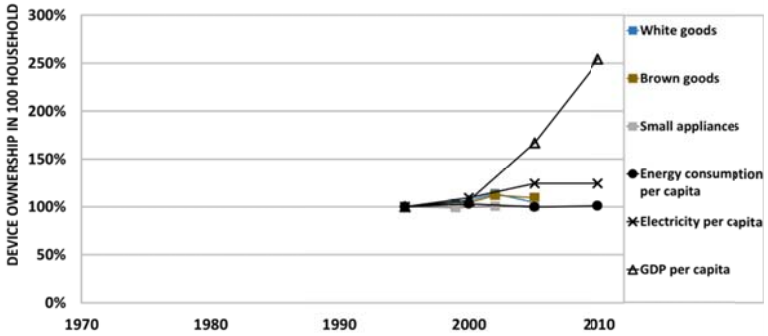


Figure 15. Trends in domestic electrical appliance ownership vs. residential energy consumption per capita, electricity consumption per capita and GDP per capita in Australia 1995-2010

4.2.2. USA

Regarding brown goods, TV penetration has reached full saturation in USA already in the early 90's, similarly to the previous cases under study. Mobile phones, desktop PCs and laptops show similar growth tends at different levels (53% to 76%, 50% to 68%, and 13% to 24%, respectively). Finally, video recorders and DVD players penetration had values at around 90% in 2000, decreasing from this point and reaching only 4% in 2009. Small appliance penetration showed stagnation or small increase for ovens (average 92%), microwave ovens (from 84% to 96%), ceiling fans (from 53% to 72%), coffee makers (61% to 72%), and toasters (from 30% to 42%). The same trend can be found for white goods, refrigerators (99%), washing machines (77% to 82%), clothes dryers (71% to 79%), air conditioners (68% to 82%), dish washers (45% to 59%), and freezers (34% to 30%) between 1993 and 2009.

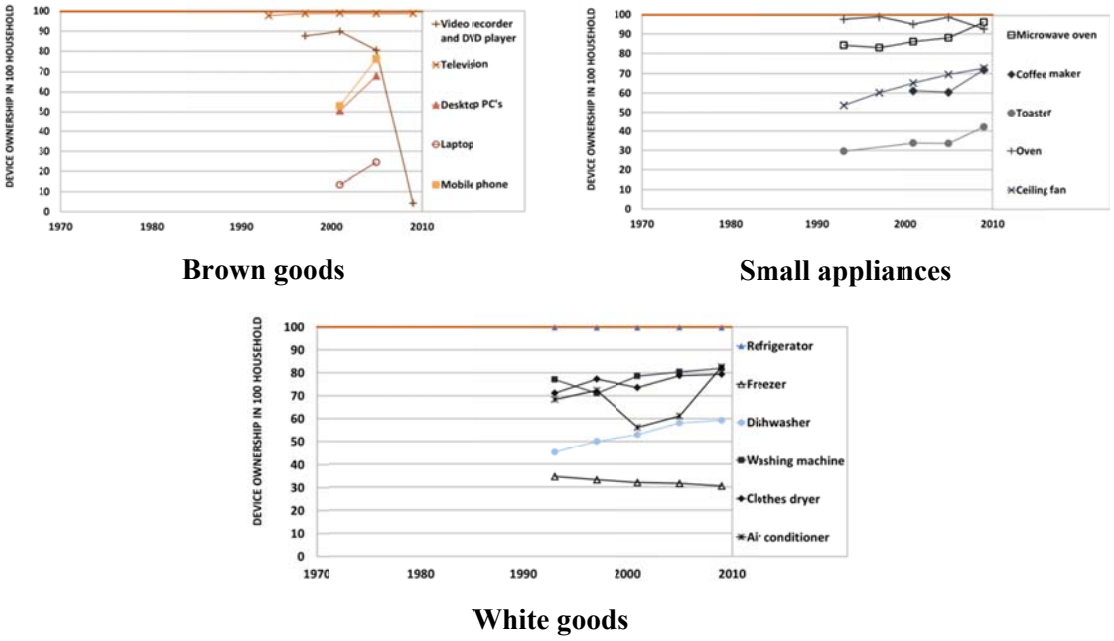


Figure 16. Penetration of domestic electrical appliances in USA 1990-2010

On the other hand, ownership data for USA in the period 2009 to 2010 is shown in Figure 17. Brown goods data is available for televisions, video recorders, desktop PCs, and laptops. Comparing ownership data to penetration data (Figure 16), it can be seen that television penetration of 100% corresponds to an ownership of 183% to 250%; video recorders and DVD players penetration was around 90% in 2001 while ownership was near 145%. Interestingly, penetration and ownership data for desktop PCs and laptops, are around 50% to 68%, and 13% to 24% in the period 2001 to 2005, for penetration respectively, while ownership is 60% to 70%, and 15% to 75% in the period 2001 to 2009, respectively. Similarly, differences can be seen in white goods between freezers and refrigerators. Penetration and ownership data are very similar in case of freezers, but different for refrigerators, where penetration is 99.8% and ownership is around 122% in 2009. Finally, Figure 18 shows ownership appliances trends in USA between 1990 and 2010 are very similar to energy and electricity consumption per capita, and lower than GDP per capita trend.

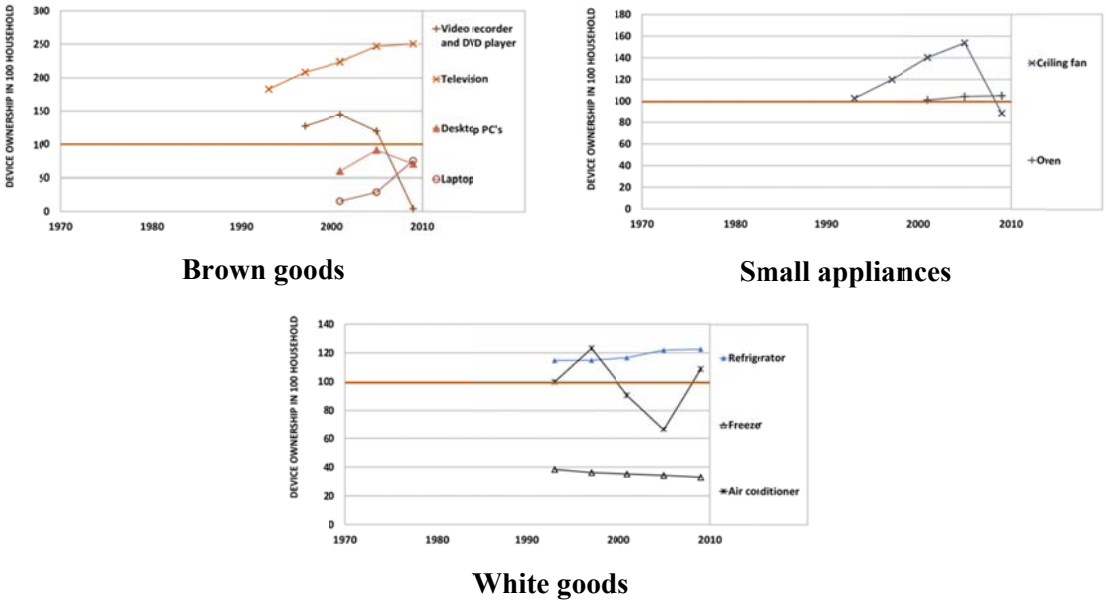


Figure 17. Ownership of domestic electrical appliances in USA 1990-2010

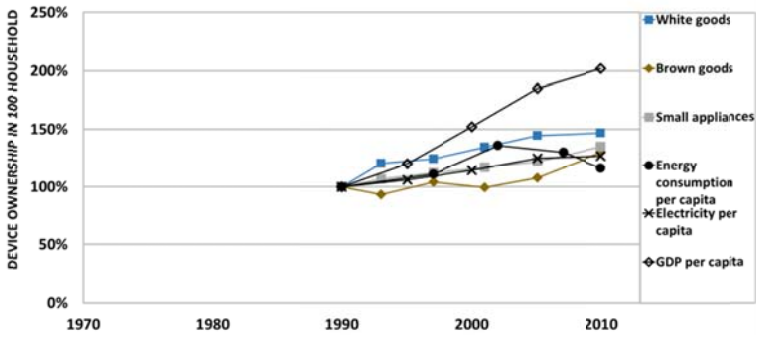


Figure 18. Trends in domestic electrical appliances vs. residential energy consumption per capita, electricity consumption per capita and GDP per capita in USA 1970-2010

Figure 19 shows that in USA refrigerators are getting bigger, although not in a significant rate. Whereas in 1993, 54% of them were of medium size and 31% were large, in 2010 52% were medium and 48% were of a size considered large. The increase in large and very large fridges is mostly due to the new additions to the stock, or the replacement of small refrigerators.

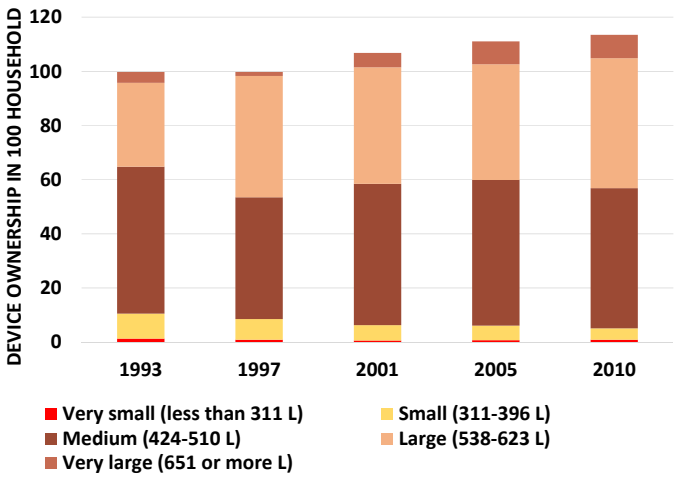


Figure 19. Trends in refrigerators size in USA 1993-2010

Figure 20 shows that in all USA households had at least one television already in 1997, and indeed, the number of televisions per household increased. In 1997, 8% of USA households had one or two televisions and 37% had four or more, while in 2009 13% households had more than two televisions and 32% had four or more.

On the contrary, computers at home have not reached saturation yet, but the number of computers per USA household is still increasing. Following this trend, the stagnation is expected to be reached in the next decades. In 1997, 6% of USA had at least one computer and 27% had two or more, while in 2009 already 33% households had at least one computer and 43% two or more.

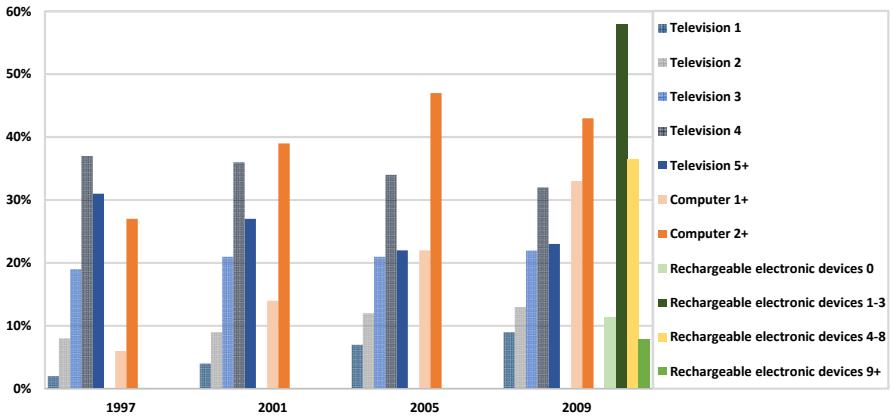


Figure 20. Trends in the household use of televisions and computers in USA 1997-2009

The number of electronic devices by household in USA in 2009 is shown in Figure 20 Televisions and computers present similar values than Figure 20. About rechargeable electronic

devices, it is remarkable that about 11% households do not have any, while 8% have nine or more; the majority of USA households have from one to three of suchdevices.

4.3. Ownership data

4.3.1. China

Chinese households achieved a remarkable increase in households' electric good ownership over the past few decades. For instance, it reached stagnation of television ownership in 2004 at 133.4%, coming up from as low as 0.59% in 1981. Fans started saturating at 167% in 1995, from 42.6% in 1981 (Figure 21). Computer ownership in China grew at a rate of 84% from 2000 to 2010. Saturation for refrigerators and washing machines was reached in 2000 from nearly 0.22% ownership in 1980. This fast increase can be seen in Figure 22 compared to residential energy consumption per capita, but this increase was lower than electricity and GDP increase per capita.

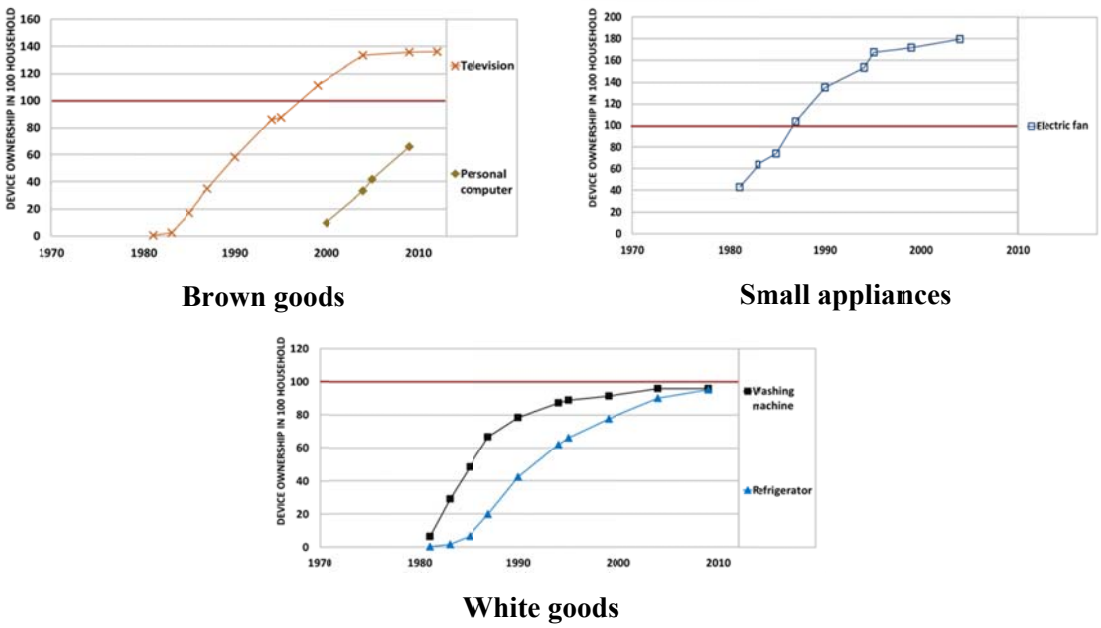


Figure 21. Ownership of domestic electrical appliances in China 1980-2010

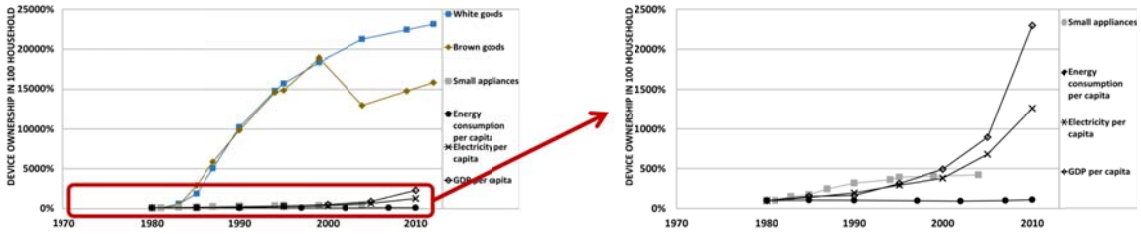
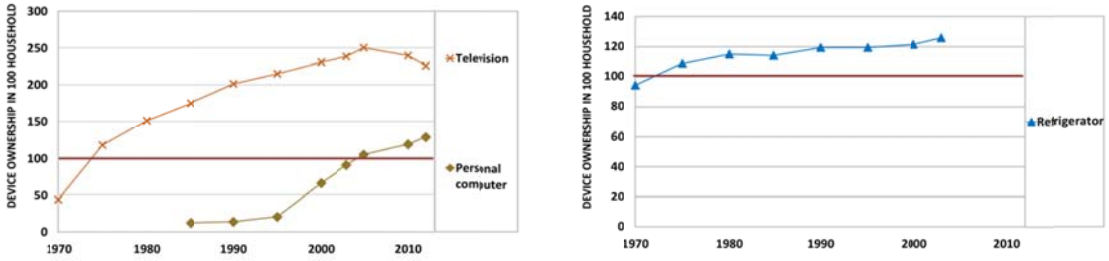


Figure 22. Trends in domestic electrical appliances vs. residential energy consumption per capita, electricity consumption per capita and GDP per capita in China 1981-2012. Note: Year 1981 is reference year (100%)

3.3.2. Japan

Figure 23 shows that in Japan appliance ownership increased over saturation rate even for computers (100% in 2004 and 118% in 2012), which in the previous countries under study did not reach stagnation yet. This is a clear sign of the technological development of the country. Televisions ownership was over 112% already in 1975 and reached 250% in 2005; similarly refrigerators ownership was over 108% in 1975 and reached 121% in 2000. White goods (refrigerators) growth was similar to energy consumption per capita and slower than electricity and much more than GDP per capita (Figure 24), while brown goods increase in Japan was dramatic since 1995 even more than GDP per capita. Again, this fact is directly related to the rapidly technological development of Japanese society. Brown goods are the appliances related to social media and leisure



Brown goods **White goods**

Figure 23. Ownership of domestic electrical appliances in Japan 1970-2012

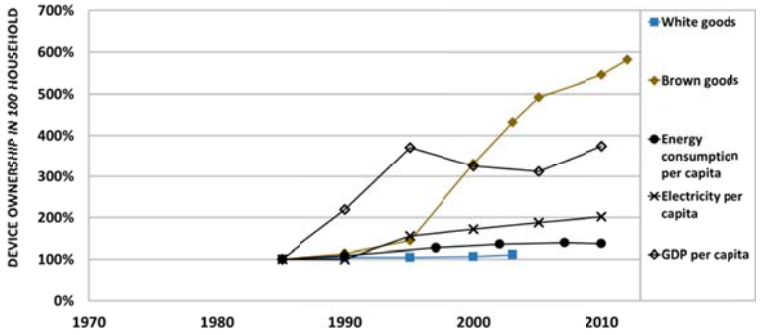


Figure 24. Trends in domestic electrical appliances vs. residential energy consumption per capita, electricity consumption per capita and GDP per capita in Japan 1970-2012. Notes: Year 1985 reference year

3.3.3. Hungary

Figure 25 shows the number of devices per household in Hungary. The appliances considered are fridges, washing machines (white goods), vacuum cleaners (small appliances), and televisions (brown goods). As it can be seen, each household in Hungary had a television in 1980, and on 2010each household has 1.6 televisions. Fridges are a special case in Hungary, since the lack of food security in the early 90s drove the population to buy more fridges and in 1990 each household had 1.6 fridges, today the average is 1.5. Vacuum cleaners ownership grew from 0.4 per household in 1970 to 0.8 in 1980, today having reached saturation. Finally, washing machines reached saturation already in 1975 and have not increased over 1 per household on average until today. In Hungary, all appliance ownership increased following the same trend as the residential energy and electricity consumption (Figure 26). GDP started to increase dramatically in 2000 after joining the NATO and the European Union in 1999 and 2004, respectively.

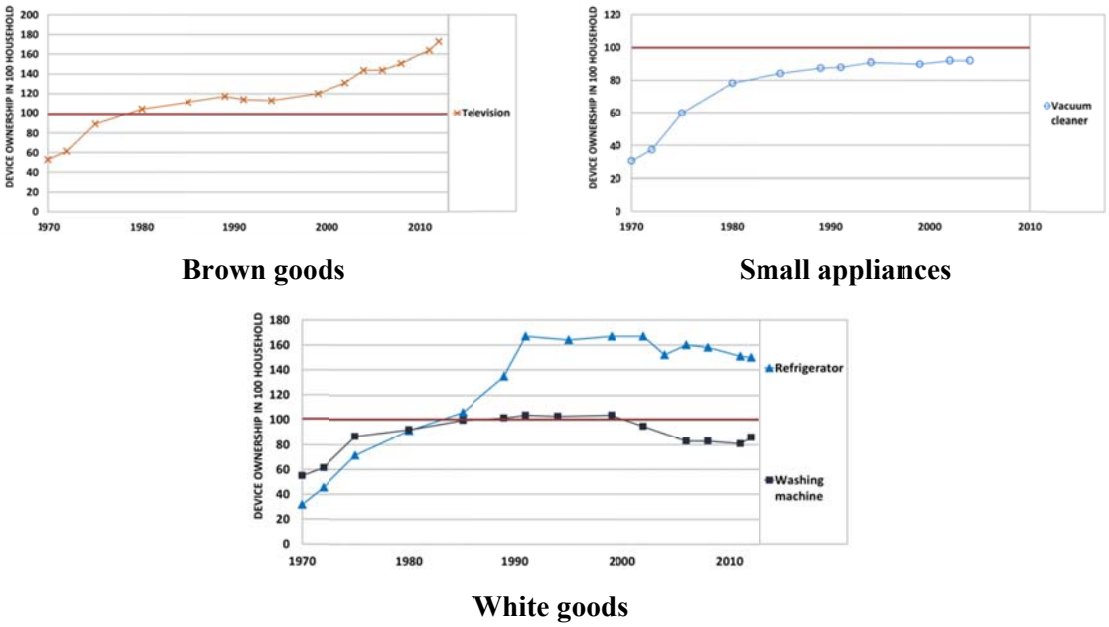


Figure 25. Ownership of domestic electrical appliances in Hungary 1960-2012

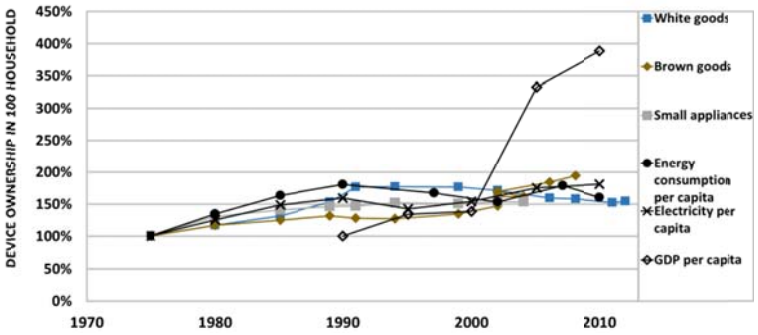


Figure 26. Trends in domestic electrical appliances vs. residential energy consumption per capita, electricity consumption per capita and GDP per capita in Hungary 1975-2010. Note: Year 1975 is reference year (100%)

4. Conclusions

This paper compiles for the first time data on appliance penetration and ownership in different countries of the world. The main purpose of the paper is not to evaluate or interpret the data, but to show trends for other researchers to use in their studies. Such information serves as the basis for relevant modelling work, policy preparatory work and other research. The main conclusion of the paper is that this data is very difficult to find and compile, most of it is available at national statistics at local language. Moreover, either penetration or ownership data is found for each country; in this paper both data is only presented for Australia (quite limited for

ownership) and USA. The objectives stated at the beginning of the paper were met along this work as follows:

1. The data was search in data bases sort by country, appliances type and year.
2. The feasibility of the data collected from the countries (from which data was found) was evaluated.
3. The data was collected for 33 appliances and 10 countries in the period from 1970 to 2010.
4. The data collected was classified following the appliances type classification (see section 2.3) and ownership/penetration data.
5. The data collected was analysed and compared to residential energy consumption per capita, electricity consumption per capita and GDP per capita.

Acknowledgements

The work is partially funded by the Spanish government (ENE2015-64117-C5-1-R). The authors would like to thank the Catalan Government for the quality accreditation given to their research group GREA and DIOPMA (2014 SGR 123 and 2014 SGR 1543, respectively). Dr. Camila Barreneche would like to thank Ministerio de Economia y Competitividad de España for grant Juan de la Cierva, FJCI-2014-22886.

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